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THE NEW FRONTIERS IN THE ATOM[1]

By Professor ERNEST O. LAWRENCE

THE UNIVERSITY OF CALIFORNIA

THE anniversary celebration of a great university is indeed an important occasion, and it is appropriate to signalize the event by a symposium on "The University and the Future of America," for a great institution of learning is eternally youthful, and youth looks always to the future. I am greatly honored to be included in this distinguished gathering, and it gives me especial pleasure to join in wishing our sister institution many happy returns.

In a discussion bearing on the future, the scientist is always in something of a dilemma. On the one hand, he is cautioned to make only very limited prognostications, for he has learned the very limited region of applicability of existing knowledge and the likelihood of error in speculation. On the other hand, he faces the future with eager excitement and curiosity about what is beyond the present frontiers of knowledge, and he is naturally tempted to speculate and indeed to indulge in daydreams. Perhaps I may convey something of what is in the minds of physicists these days by a brief discussion of some recent developments of the current intensive attack on the new frontier in the atomic world—the nucleus of the atom.

[1] An address delivered at the fiftieth anniversary celebration of Stanford University, June 16. It will appear with illustrations in a volume to be published by the Stanford University Press.

ATOMS

The atomic constitution of matter has long been a keystone of natural science. At the beginning of this

century it was a keystone in a structure having as pillars the principles of the conservation of energy and the indestructibility of matter. In the nineties, it was almost axiomatic to say that the building blocks of nature are the atoms—indivisible, indestructible entities, permanent for all time. But the discovery of radioactivity altered all this. There followed the discovery of the electron and the proton as smaller and more fundamental constituents of matter and the atom itself became the happy hunting ground of the experimental physicist. Atomic physics developed rapidly; for the atom was found to be a domain of almost incredible richness, and to-day, thanks perhaps to the newspapers, our children speak knowingly of smashing atoms!

To explain the wonderful phenomena of radioactivity, Rutherford came forward in 1904 with a revolutionary hypothesis which reduced the complicated and mysterious observations of radioactivity to simple order. According to Rutherford, not all the atoms have existed for ages and will exist for all time, but there are some atoms in nature that are energetically unstable and in the course of time, of their own accord, blow up with explosive violence. These are the natural radioactive substances, and the fragments given off in the atomic explosions are the observed penetrating rays.

It was not long before Rutherford's hypothesis was established as a law of nature and formed a greater keystone, replacing the chemists' conception of the atom and serving as a foundation for a new science, the science of the atomic nucleus.

Time does not permit an adequate historical résumé of the development of nuclear physics, but for the present purpose it is sufficient to say that the ideas of Rutherford and Bohr on the structure of atoms are now firmly established. There is an abundance of evidence that an atom consists of a nebulous cloud of planetary electrons whirling about a very dense sun, the positively charged nucleus, and that it is in the nucleus that the atomic explosions of radioactivity occur. Indeed, our assurance that this is so rivals our confidence that the planets revolve about the sun!

Atomic Nucleus

Let us now proceed immediately to a consideration of the structure of the nucleus. The nucleus consists of a closely packed group of protons and neutrons, elementary building blocks of nature some 2,000 times heavier than the electrons. The neutrons are electrically neutral while the protons carry positive charges and for each proton in the nucleus there is a corresponding negative electron outside, for the atom as a whole is uncharged. Since the number of electrons outside determines the ordinary chemical and physical properties of the atom, it follows that the nuclear charge determines the place of the atom in the periodic table of the elements.

Thus, the nucleus is the body and soul of the atom. More than 99.9 per cent. of the atom's mass is in the nucleus and the nuclear charge determines the nature of the atom, its chemical and physical properties.

Transmutation of the Elements

These considerations reduce the age-old problem of alchemy to simple terms. For we see to change one element into another is simply to change the nuclear charge, *i.e.*, the number of protons, in the nucleus. The subject of transmutation of the elements has recently received a great deal of attention in the laboratory. All sorts of transmutations have been produced in a minute scale—helium has been made from lithium, magnesium from sodium and even mercury has been turned into gold. The day may come when we will indeed possess the philosopher's stone and will be able to transmute the elements on a grand scale. But interesting as these developments are, I should like to draw your attention to two other subjects, artificial radioactivity and the question of tapping the vast reservoir of energy in the nucleus of the atom.

Artificial Radioactivity

One of the early results of atomic bombardment was the discovery that neutrons could be knocked in or knocked out of the nucleus to produce radioactive isotopes of the ordinary elements. Thus, for example, the nucleus of the ordinary sodium atom contains 11 neutrons and 12 protons, 23 particles in all, and so it is called sodium 23 (or Na^{23}); and by bombardment it was found that a neutron could either be added to make sodium 24 or subtracted to make sodium 22, both isotopic forms not occurring in the natural state. The reason that these synthetic forms are not found in nature is that they are energetically unstable. They are radioactive and in the course of time blow up with explosive violence. Sodium 24 has a half-life of 14.5 hours, *i.e.*, it has an even chance of disintegrating in that time, turning into magnesium by the emission of an electron. Sodium 22, on the other hand, has a half-life of 3 years and emits positive electrons to turn into stable neon 22.

These artificial radioactive isotopes of the elements are indistinguishable from their ordinary stable relatives until the instant they manifest their radioactivity. This fact deserves emphasis, and it may be illustrated further by the case of chlorine. Chlorine consists of a mixture of two isotopes, 76 per cent. of Cl^{35} and 24 per cent. of Cl^{37}, resulting in a chemical

atomic weight of 35.46 which is the average weight of the mixture. By elaborate technique, to be sure, it is possible to take advantage of the extremely slight difference in chemical properties and bring about separation of these isotopes, but in ordinary chemical, physical and biological processes, the chlorine isotopes are indistinguishable and inseparable. The artificial radioactive isotopes Cl^{34} and Cl^{38} are likewise indistinguishable. In fact, Cl^{34} is more nearly identical in properties to the natural isotope Cl^{35} than is the other natural isotope Cl^{37}. And again I would say that the radioactive characteristic of Cl^{34} becomes evident only at the moment it blows up to turn into the neighbor-element sulfur.

Radioactive Tracer Atoms

In these radioactive transformations of the artificial radioactive isotopes, the radiations given off are so energetic that the radiations from individual atoms can be detected with rugged and reliable instruments, called Geiger counters. Thus, radioactive isotopes can be admixed with ordinary chemicals to serve as tracer elements in complicated chemical or biological processes.

As an illustration of the power of this new technique of labeling and tracing atoms, let us consider iodine in relation to the thyroid gland. It is well known that the thyroid takes up and stores iodine, and this fact can be demonstrated strikingly by feeding an individual iodine including a small quantity of radioactive iodine. Before the feeding, the radioactivity of the food can be measured by placing it near a Geiger counter, thereby giving a measure of iodine content. Later the progress of the iodine through the body can be observed by placing the Geiger counter next to various parts of the body. Likewise, the proportion of the fed iodine in the various body fluids at any time can be determined quickly by taking small samples of the fluids and measuring their radioactivity. After some hours it is found that a large part of the iodine taken in has collected in the thyroid, a fact that is readily established by placing a Geiger counter next to the gland [lantern] and observing the activity while finding no appreciable activity elsewhere. This technique makes it possible to study the behavior of the thyroid in health and in disease, and much interesting work along this line has been carried out recently.

Radio-autography

Although the tracer elements are readily detected with the Geiger counter, there is a photographic method which for many purposes has obvious advantages. This method is sometimes called radio-autography and is illustrated by the lantern slide. Here a minute amount of radioactive phosphorus in the form of sodium phosphate was added to the nutrient solution of a tomato plant, and after a day or so leaves were placed against a photographic film enclosed in a light-tight paper envelope. The penetrating rays from the radioactive phosphorus produced the developed contact image shown, which gives an accurate and detailed picture of the uptake of phosphate by the plant. Now, indeed, the same method works very well also for the thyroid, as is shown in the lantern slide, which is a photomicrograph of a thin section of thyroid tissue containing radio-iodine; alongside is the radio-autograph obtained from the same micro section by placing it against a photographic plate. The distribution of the iodine in various parts of the gland is shown in surprising detail.

Similarly striking radio-autographs of the distribution of phosphorus and strontium in rats are shown in the lantern slide. Here two rats were fed radio-phosphorus and radio-strontium respectively, and then some hours or days later they were sacrificed, and frozen sections of the entire bodies of the animals were placed against a photographic plate. The resulting radio-autographs show clearly that both strontium and phosphorus are selectively deposited in the bones, phosphorus being more widely distributed in other tissue. The distribution of the strontium in the bones also appears to be quite different from that of phosphorus as radio-autographs of the sections of bones clearly show [lantern].

These examples serve to illustrate the power of the new technique of radioactive tracer atoms. It has often been said that the progress of science is the progress of new tools and new techniques, and I think we may look forward to accelerated developments in biology resulting from the tracer elements.

Artificial Radioactive Substances in Therapy

It is somewhat afield for me to discuss medical problems, but I should like to direct your attention to the possibilities of the artificial radioactive substances in the treatment of cancer and allied diseases. It is well known that at the present time there are two main approaches to the treatment of neoplastic disease, surgery and radiation. It is sometimes possible to cut out a cancer completely and effect a cure, and in other circumstances, it is possible to destroy a tumor by irradiation with x-rays or radium. The mechanism whereby the radiation destroys the tumor without destroying an excessive amount of surrounding normal tissue is doubtless extremely complicated, but in any case it is evidently important to localize the radiation to the tumor as much as possible. Perhaps the ideal would be approached if a means were at hand to

irradiate each and every malignant cell without irradiating a single normal cell.

The artificial radioactive substances open for the first time the possibility of an approach to such selective irradiation of tissue. The above examples of tracers suggest the treatment of thyroid tumors with radioactive iodine, bone tumors with radioactive strontium and radioactive phosphorus. These possibilities are being investigated as is the more specific problem of finding a radioactive substance that is selectively taken up by tumor tissue. If there were time, I should like to describe work along this line in progress in several laboratories, and especially to speak of the important progress that is being made in the treatment of leukemia, but I must content myself with only mentioning these new developments in medicine, which are so promising for the future.

Atomic Energy

For a long time astronomers have been vexed with a problem, the problem of the source of stellar energy, for there is evidence that the sun has been blazing at its present brilliance for thousands of millions of years, and no ordinary fuel could be responsible for such an eternal fire.

The discovery of radium posed to the physicist a similar difficulty; for it was found that radium gives off every hour enough energy to heat its own weight of water to boiling, and this it continues to do for more than a thousand years. Such a vast source of energy in the radium atom was as difficult to understand as the evidently limitless store of heat in the sun. The problem was of fundamental interest and all sorts of possibilities were considered even to the abandonment of the principle of the conservation of energy.

But the first clue to the solution of the problem appeared in 1905 when Einstein announced the theory of relativity. One of the revolutionary consequences of the theory was that matter is a form of energy and that presumably in nature processes go on in which matter is destroyed and transformed into more familiar forms of energy such as heat, radiation and mechanical motion. The relativity theory gave as the conversion factor relating mass to equivalent energy, the square of the velocity of light, a very large number, even to an astronomer! Thus, the theory indicated that, if a glass of water were completely destroyed, more than a billion kilowatt hours of energy would be released, enough to supply a city with light and power for quite a time!

This exciting deduction was immediately accepted by the astronomers, who said, "Doubtless within the sun conditions are such that matter is being transformed to heat. Thus, slowly through the ages the sun is losing mass; its very substance is radiating into space."

Likewise, the physicists, who had other compelling reasons for accepting the Einstein theory, concluded that the source of the energy in the radium atom was a destruction of matter in the atomic explosion giving rise to the penetrating rays.

Although the fundamental assumptions on which the relativity theory was based were evidently sound, and the explanations of the source of energy of the sun and stars and radioactivity were most attractive, until direct experimental verification was forthcoming, Einstein's great deduction could not be regarded as an established law of nature.

The first direct evidence of the truth of this fundamental principle was obtained in the first atom-smashing experiments a decade ago. It was observed that, when the nucleus of a lithium atom is hit by a proton having a kinetic energy of less than a million electron-volts, the result is the formation of two helium nuclei which fly apart with an energy of more than 17 million electron-volts; thus in the nuclear reaction in which hydrogen and lithium unite to form two helium atoms, there is a great release of kinetic energy.

Now one of the interesting and important occupations of the experimental physicist has been the measurement of the masses of atoms and the weights of atoms are known with great precision—much greater than any individual knows his own weight. In particular, it was known precisely that a lithium atom and a hydrogen atom have a total weight slightly greater than the weight of two helium atoms, and it was a great triumph for the Einstein theory when measurements showed that the excess kinetic energy with which the helium atoms flew apart in the hydrogen-lithium reaction corresponded exactly with the disappearance of mass according to the mass energy relation. Literally hundreds of similar nuclear reactions have been studied in the intervening years, and in each instance the Einstein relation has been verified. At the present time this great principle has as firm an experimental foundation as any of our laws of nature.

Uranium Fission

Now that it is an experimental fact that matter can be converted into energy, it becomes of great practical importance to inquire whether the vast store of energy in the atom will be tapped for useful purposes. This question has recently taken on added interest through the discovery of a new type of nuclear reaction involving the heavy element uranium.

It has been known for some years that the heavy

elements, such as lead, gold and uranium, are relatively heavier than the middle weight elements, as copper and iron, or more precisely that the average weight of the neutrons, protons and electrons in the heavy elements is greater than their average weight in the atoms near the middle of the periodic table. Accordingly, it is to be expected that, if heavy atoms were split approximately in two, forming corresponding middle weight atoms, there would be a vast release of energy corresponding to the disappearance of matter in the transformation. Indeed, from known values of the masses, it can be calculated on the basis of Einstein's mass-energy relation that each splitting or fission, as the process is called, of a uranium atom into two approximately equal parts releases an energy of about 200 million electron-volts, which is millions of times more heat per atom than is given off when ordinary fuel is burned. Thus, calculations show that 100 pounds of uranium would yield a billion kilowatt hours, which at one cent per kilowatt hour would be ten million dollars' worth of electrical energy.

For some time these considerations were largely academic because no way was known for producing fission of the heavy elements. But interest in the matter has now become extremely lively as a result of the discovery that fission of uranium is actually brought about by bombarding it with neutrons.

The phenomenon has, during the past two years, received intensive study in laboratories all over the world, and several salient facts have emerged. First, the rare U^{235} isotope undergoes fission after absorption of a slow neutron. Second, the energy released in the fission process has been measured; and, as expected, it is found that, when a neutron having an energy less than an electron-volt enters the U^{235} nucleus, about 200 million electron-volts of energy is released. Third it is found also that the fission process is so violent that usually the U^{235} nucleus does not break up into two parts only, but more often several neutrons are given off in addition to the two large fragments.

That neutrons are generated in the fission process is of the greatest interest because it opens up the possibility of a chain reaction, a series of nuclear reactions wherein the neutrons liberated in one fission process go on to produce additional fissions in other atoms which in turn give rise to more neutrons which produce further fissions and so on. It is this possibility of a chain reaction that has excited the interest in uranium as a practical source of atomic energy.

Without going into further detail, it is perhaps sufficient to say that there is some evidence now that, if U^{235} could be separated in quantity from the natural mixture of the isotopes, a chain reaction could, indeed, be produced. But herein lies the catch, for there is no practical large-scale way in sight of separating the isotopes of the heavy elements, and certainly it is doubtful if a way will be found.

But I should not want to indicate that the uranium matter is a disappointment, that after all we shall never find a way to bring about fission of the heavy elements for useful purposes. Quite the contrary!

The present situation is not unlike the circumstances fifty years ago surrounding the then great question of whether man would ever be able to fly. In those days the fundamental laws of classical mechanics were known, and they allowed the possibility of heavier than air flight. Moreover, there was an abundance of supporting observational evidence that flight should be possible; there were kites and there were the birds of the air. But man's realization of the dream awaited primarily the development of the combustion engine, a circumstance not so evidently connected with the fundamental problems of flight. Likewise the fundamental laws of nature recently revealed to us allow the possibility of obtaining useful nuclear energy, and radium and the sun and stars bear witness that this vast source of energy is being tapped in nature. Again success in this direction may await the development of a new instrument or technique just as the airplane depended on the gas engine.

Perhaps the problem awaits a deeper understanding of the forces that hold nuclei together. That there are little understood forces operative in the nucleus is more than evident; especially from observations of the cosmic rays, it has been established that particles of matter called mesotrons of intermediate mass between electrons and protons play a dominant role in nuclear structure. Theoretical considerations suggest that the mesotrons may be connected with the primary forces in the nucleus, and accordingly, an understanding of mesotron forces may ultimately yield the solution of the practical problem of atomic energy.

THE GIANT CYCLOTRON

In order to study experimentally the mesotron problem, it is necessary to bombard nuclei with atomic projectiles having energies in the range of 100 million electron-volts rather than in the neighborhood of 10 million electron-volts at present available in cyclotron laboratories. To this end a giant cyclotron is now under construction on Charter Hill in Berkeley, and I should like to conclude with some pictures of this great machine. Whether it will be the key to the vast store of energy in the atom, what new discoveries, what new insight into nature it will bring—only the future will tell!

OBITUARY

HOWARD WALTON CLARK

HOWARD WALTON CLARK, curator of the department of ichthyology of the California Academy of Sciences, died on August 10, after a short illness. He was born in Allen County, Indiana, on September 9, 1870, gained his early education in public schools, and graduated from Indiana University in 1896, receiving the A.M. degree in 1901. From his earliest boyhood his interests turned toward natural history, and it almost instinctively became his life work. He served as preparator in the Field Museum, Chicago, from 1901 to 1904, and as assistant in the U. S. Bureau of Fisheries from 1904 to 1909. From 1910 to 1923 he was scientific assistant in the Biological Station of the U. S. Bureau of Fisheries at Fairport, Iowa, largely engaged in the study of the life history and economic importance of the fresh-water mussels and similar problems. In 1923 he went to California and served as collector and aquarist for the newly opened Steinhart Aquarium of the California Academy of Sciences until 1925, when he became assistant curator of the department of fishes in the museum of the academy from 1925 to 1933, and the curator of ichthyology from 1933 until his death.

Mr. Clark was a versatile naturalist, equally at home in both zoology and botany, a keen and tireless observer in the field and laboratory. Aside from a considerable number of other publications in systematic zoology and botany, his collaboration with the late Dr. Barton Warren Evermann produced their masterly study "Lake Maxinkuckee, a Physical and Biological Survey," in two volumes, issued by the Department of Conservation of the State of Indiana in 1920, which stands as a classic in its field. In addition to much of the first volume the second, dealing with the flora of the region, is almost entirely the work of Mr. Clark. It is based upon field studies extended through several years at intervals, and much interrupted by other work, and is not merely a list of plants collected, but is rich in ecological detail, enlivened here and there with bits of description of high literary merit. As joint author with David Starr Jordan and Barton Warren Evermann he published in 1930 their large "Check List of the Fishes and Fish-like Vertebrates of North and Middle America," invaluable for the systematic ichthyologist. The extension and revision of this work has been continuously carried on by Mr. Clark since its appearance with the idea in mind of a revised edition. In addition to his own studies he edited the notices of ichthyological literature appearing in *Biological Abstracts* since its foundation, and countless careful reviews appearing in it were his faithful work.

A man of wide interests, a cordial and sincere personality, blessed with a keen sense of humor, he was at all times helpful and stimulating to his colleagues, and ever ready to promote their interests and those of the academy he served so well.

F. M. MACFARLAND
CALIFORNIA ACADEMY OF SCIENCES

DEATHS AND MEMORIALS

DR. WILLIAM NEWTON LOGAN, until his retirement in 1936 professor of economic geology and mineralogy at Indiana University and state geologist of Indiana, died on August 27 in his seventy-second year.

AUGUST EIMER, who retired ten years ago as president of the drug and chemical firm of Eimer and Amend, New York City, died on August 28.

THE death by suicide on August 25 is reported of Walters Moseley, professor of chemistry and head of the department of Tulane University. He was fifty-three years old.

DR. A. J. CLARK, professor of materia medica in the University of Edinburgh, died on July 30 at the age of fifty-six years.

A WIRELESS dispatch to *The New York Times* dated August 26 states that Dr. Kazimierz Bartel, professor of mathematics at the University of Lwow and at the Polytechnic Institute, prime minister of Poland from 1926 to 1930 and senator in 1935, has been shot by the Gestapo. The dispatch states that sixty professors of the University of Lwow, in which Professor Bartel taught, have been arrested and that their fate is unknown. According to the Associated Press, Professor Bartel refused to leave Lwow when the Russians withdrew after the outbreak of the German-Russian war, and was arrested when the Nazis took over the city. He was fifty-nine years old.

THE correspondent of the London *Times* at Buenos Aires, under date of August 4, writes: "In the presence of the British and United States Ambassadors, a bronze plaque was unveiled yesterday to the memory of William Henry Hudson at Berazategui, in the province of Buenos Aires, to commemorate the centenary of the writer's birth. Dr. Fernando Pozzo, president of the Committee of Homage, announced the foundation of the Association of the Friends of Hudson, whose chief objects, he said, would be to acquire the property of Veinte y Cinco Ombues, in Quilmes, the suburb of Buenos Aires where Hudson was born, and to create there a bird sanctuary and a museum of ornithology."

SCIENTIFIC EVENTS

THE ROYAL OBSERVATORY, GREENWICH[1]

THE annual report of the Astronomer Royal, just published, refers to the work of the Royal Observatory during the period May 1, 1940–April 30, 1941. To those who know the position of the observatory, in the midst of military and industrial objectives, it will come as no surprise that much of the work has been curtailed by enemy action. The last report mentioned the dismantling of much of the optical apparatus; most of the mirrors and lenses have now been sent away from Greenwich for safety. Since heavy bombing of London started last September, night observations have been impossible on such of the telescopes as had not already been dismounted at the outbreak of hostilities; in fact, the only observing programs still carried on at Greenwich are daylight ones, namely, the routine meteorological work and the photographic and visual solar observations.

The public time service functions well from two emergency outstations, as the familiar "six pips" regularly testify. The Rugby rhythmic signals, however, in present circumstances fall short of the high precision needed for control of frequency standards, though they are, of course, quite adequate for navigation. Rating of chronometers and watches and their issue to the Royal Navy continue as usual, though the entire establishment concerned has been moved for the second time in two years.

Work has ceased on the Airy transit circle after continuous observation with this instrument for ninety years. More than 650,000 observations have been made with it, forming the most important contribution from a single instrument to fundamental positional astronomy. The new reversible transit circle which is to take its place has obtained nearly 10,000 transits during the last three years. When observing ceased in September, 1940, the work of determining the division errors had been completed and an investigation started on the irregularities of the pivots. These latter have already been found to be extremely small.

The photoheliograph and spectrohelioscope observations show the expected decline in solar activity from the 1937–38 maximum, the sunspot frequency having dropped to about half that at maximum. Nevertheless, twenty-one large groups of spots occurred, six of them being later associated with magnetic storms. One of these latter, that of March 1, 1941, ranks high among the most severe disturbances of the past ninety years. The associated spot could not be extensively observed because of cloud, but the number of short-wave radio fade-outs occurring during its central meridian passage suggests that it was chromospherically very active. Over the year as a whole, however, both chromospheric eruptions and radio fade-outs were few.

The meteorological department of the observatory has celebrated its centenary of routine observations. Features of the year's weather include an August drier than any for 122 years, and a period from December to April during which each month was considerably colder than normal, the temperature in the Stevenson screen never reaching 59° F. for the whole five months.

Discussion of the photographic material, comprising nearly 3,000 plates, obtained during the 1931 opposition of Eros, is now practically complete. The solar parallax deduced from these observations at stations all over the world is $8 \cdot 790'' \pm 0 \cdot 001''$, the previously accepted value being $8 \cdot 80''$.

The "Nautical Almanac" office continues its essential work, though it has had to contend with the destruction by fire of the whole of the type and plates for all its publications except the "Astronomical Navigation Tables." The consequent delay in publication is being rapidly made good, in some cases by using photographic reproduction in lieu of printing from type.

Astronomers all over the world will join in sympathizing with the Astronomer Royal and his staff on the interruption of many of their long-established programs, and in congratulating them on their maintenance of essential services throughout a very trying period.

[1] From *Nature*.

COSMIC RAY INVESTIGATIONS

RESULTS of cosmic ray investigations in the Andes ranging up to 19,200 feet—nearly a mile higher than the highest peak in the United States—were reported on his return to the United States on August 22 by Dr. Arthur H. Compton, of the University of Chicago, leader of the expedition. These are, according to the official announcement:

1. At an altitude of more than 15,600 feet on the site of a Cerro de Pasco Corporation mine near Oroya in central Peru, Drs. Ernest O. Wollan and Donald Hughes photographed tracks of cosmic ray particles with a cloud chamber. They had 9,000 pounds of equipment, including the large permanent magnet used in high altitude experimental airplane flights in this country. Their chief finding was clear photographic evidence of the production of groups of positive and negative mesotrons.

2. Working on Mount El Misti in southern Peru at altitudes up to 19,200 feet, Dr. Norman Hilberry and his wife, Dr. Ann Hepburn Hilberry, verified fundamental

theories on the origin of giant cosmic ray showers, establishing the "peak" of their occurrence at approximately 16,000 feet.

3. Staging the first stratosphere balloon flights at the equator seeking information on mesotrons, rays produced by collision of a cosmic ray and nucleus of an atom in the atmosphere, Drs. William P. Jesse, of the University of Chicago, and Paulus A. Pompeia, of the University of São Paulo, Brazil, have already recovered one flight which is now being studied and are continuing their investigations.

The University of Chicago expedition, aided by the Nelson Rockefeller Committee on Cultural and Commercial Relations between the American Republics, started two months ago. Its members included Dr. Pompeia, of the University of São Paulo, who had been at the University of Chicago for the last year; Professor Norman Hilberry, now of New York University, and other members of the scientific staff of the University of Chicago.

The expedition had as its scientific objectives procurement of data from equatorial locations and elaboration of experiments conducted in the United States at various elevations.

The Oroya investigations were similar to those conducted in the Denver mountain parks, cooperatively by the University of Denver, the Massachusetts Institute of Technology, Cornell University and the University of Chicago. At the Oroya site, however, the investigators were able to get the same equipment to a point a thousand feet higher than any mountain in this country. The resulting pictures of tracks of cosmic ray particles show production of groups of positive and negative mesotrons and lay the basis of possible analysis of the particles.

At the Oroya site, the same permanent magnet was used as in high-altitude plane flights made two years ago at Chicago for cosmic ray investigations. With the advantage of longer time and less cramped conditions for observations, evidence corroborating indications from the airplane observations was procured.

The Hilberrys set up three observation stations on El Misti, at 7,500, 15,500 and 19,200 feet, using a mule train to reach their posts and carrying oxygen, though they did not find it necessary to use it. The same height for observations was reached in the Himalayas nine years ago, but reaching this height required two weeks against a day and a half in the Andean location. The El Misti base was at Arequipa.

The chief finding of the El Misti investigation was the greatest abundance of giant showers of cosmic rays at approximately 16,000 feet and laying of groundwork for reliable estimates of the maximum energy in primary cosmic ray particles. The theory had been that the showers of cosmic rays developed as they came down through the atmosphere. With observations made at the 16,000-foot or peak-level, t theory was corroborated. The maximum energy in t primary cosmic ray particle is estimated by physicis at approximately ten billion times the energy releas by a radium ray, or enough energy in a single at to lift one's finger off the table.

The balloon flights staged by Drs. Pompeia and Je at São Paulo were designed to investigate further t hypothesis that the cosmic ray particle entering t earth from outside the atmosphere is the proton; a to discover whether mesotrons are produced wi higher energy at the top of the atmosphere near t equator than at the top of the atmosphere ov Chicago.

Other flights have been made from the equator, b these are the first flights designed for mesotron in formation. The results will be compared with result of similar flights in Texas and Chicago to determin the comparative energies in various parts of the ceil ing of the atmosphere.

COMMISSION TO CHINA ON MALARIA CONTROL

AT the request of the Chinese Government, thi country will send a commission of medical and sani tary officers and entomologists to control malaria an supervise sanitation and medical care of 250,000 Chi nese laborers to be employed in the construction of railroad in the Chinese Province of Yunnan. The commission is appointed by Surgeon General Thoma Parran and will be headed by Dr. V. H. Haas, of the Public Health Service. It will consist of some sixteen American members.

The malaria control will be undertaken in one of the most highly malarious sections of China. In addition, general sanitary and medical supervision of the workers will be undertaken by the commission. Approximately $1,140,000 has been supplied the project by this government under terms of the Lend-Lease Act. Salaries of laborers and of medical and sanitary officers supplied by the Chinese Government will be paid by China. The $1,140,000 will pay for salaries and expenses of the American members of the commission and for drugs and chemicals and medical supplies.

The Rockefeller Foundation was asked to assist by making available the services of some of its personnel. D. E. Wright, a sanitary engineer on the staff of the International Health Division, has been assigned for full-time service with the commission. Dr. Marshall C. Balfour, regional director for the International Health Division in the Far East, is serving intermittently as consultant. There will also be cooperation with the laboratory for malaria investigations at Chefang on the Burma Road.

Members of the commission will leave for China at

intervals beginning on September 21, when Dr. Haas will leave San Francisco by clipper. It is expected the commission will operate for about a year.

THE FIFTIETH ANNIVERSARY OF THE UNIVERSITY OF CHICAGO

THE closing events of the celebration of the fiftieth anniversary of the University of Chicago will be held from September 22 to 29. The exercises will center about the subject of "New Features in Education and Research." Details of the program have been printed in the issues of SCIENCE for July 11 and August 15.

Attendance is expected to reach ten thousand. The American Association for the Advancement of Science will meet at the university during the week. Many scientific men from this country and abroad, including many refugee scholars, are expected to be present.

At the anniversary convocation on September 29 President Robert M. Hutchins will make an address and thirty-four honorary degrees will be conferred. The academic festival will end with a luncheon for the visiting delegates of more than four hundred colleges, universities, research institutions and learned societies. Speakers after the luncheon will be President James B. Conant, of Harvard University; President Robert G. Sproul, of the University of California, and President Mildred McAfee, of Wellesley College.

Preceding the special convocation on September 27, President Homer P. Rainey, of the University of Texas, and President Hutchins will speak at the annual alumni assembly; Professor Louis Gottschalk will speak at the Phi Beta Kappa dinner, and official delegates from colleges and universities will attend a reception given by deans of the university.

On Sunday, September 28, an anniversary service of commemoration and thanksgiving will be held in Rockefeller Memorial Chapel, followed by a reception for the delegates given by President and Mrs. Hutchins. President Hutchins will be among the speakers on a special broadcast of the University of Chicago Round Table on the nationwide red network of the National Broadcasting Company at 1:30 P.M. At 8:30 P.M. a special festival concert by the Chicago Symphony Orchestra under the direction of Dr. Frederick Stock will be given in Rockefeller Memorial Chapel.

The festival will follow five days devoted to the meetings of learned societies (September 22 to 26), in which more than a hundred and sixty scientific workers and scholars, including the thirty-four who will be the recipients of honorary degrees, will describe the results of their works.

SYMPOSIA AT THE ATLANTIC CITY MEETING OF THE AMERICAN CHEMICAL SOCIETY

AN extensive program of symposia has been arranged by the various divisions of the American Chemical Society for the Atlantic City meeting, which will be held from September 8 to 12. They are as follows:

Division of Agricultural and Food Chemistry, Gerald A. Fitzgerald, *chairman.* "New Analytical Tools for Biological and Food Research." (Joint symposium with the Divisions of Biological Chemistry and Medicinal Chemistry), G. A. Fitzgerald, presiding.

Division of Biological Chemistry, Herbert O. Calvery, *chairman.* "Physicochemical Methods in Protein Chemistry." (Joint symposium with the Division of Physical and Inorganic Chemistry), D. A. MacInnes, presiding. "The Chemistry of Aging," Anton J. Carlson, presiding. "New Analytical Tools for Biological and Food Research." (Joint symposium with the Division of Agricultural and Food Chemistry and Medicinal Chemistry.)

Division of Chemical Education, R. D. Reed, *chairman.* "Professional Training of Chemists or Chemical Engineers," R. D. Reed, presiding.

Division of Fertilizer Chemistry, H. B. Siems, *chairman.* "Phosphates." (Joint symposium with the Division of Industrial and Engineering Chemistry.)

Division of Industrial and Engineering Chemistry, B. F. Dodge, *chairman.* "Unit Processes," R. Norris Shreve, presiding. "Symposium on Phosphates." (Joint symposium with the Division of Fertilizer Chemistry.) "Electrical Insulation Materials," R. N. Evans, presiding.

Division of Medicinal Chemistry, R. J. Fosbinder, *chairman.* "New Analytical Tools for Biological and Food Research." (Joint symposium with the Divisions of Agricultural and Food Chemistry and Biological Chemistry.)

Division of Paint, Varnish and Plastics Chemistry, G. G. Sward, *chairman.* "Progress in High Polymer Plastics," S. L. Base, presiding.

Division of Physical and Inorganic Chemistry, J. G. Kirkwood, *chairman.* "Physicochemical Methods in Protein Chemistry." (Joint symposium with the Division of Biological Chemistry.) "Magnetism and Molecular Structure," P. W. Selwood, presiding. "Elementary Reactions," F. O. Rice, presiding.

Division of Rubber Chemistry, R. H. Gerke, *chairman.* "Rubber for Defense," R. H. Gerke, presiding.

SCIENTIFIC NOTES AND NEWS

DR. WILLIAM LLOYD EVANS, professor of chemistry and chairman of the department of the Ohio State University, will deliver on September 10 the presidential address before the American Chemical Society meeting at Atlantic City. He will speak on "Some Less Familiar Aspects of Carbohydrate Chemistry."

At the dinner of the society on the evening of the same day an address entitled "The Chemical Warfare Service in National Defense" will be made by Major General William N. Porter, chief of the service. Addresses will be given at the opening meeting on September 8 by H. V. Churchill, of the Aluminum Company of America, on "Industrial Spectrochemical Analysis"; by Dr. B. L. Clarke, of the Bell Telephone Laboratories, on "The Electrographic Method of Analysis," and by V. K. Zworykin and James Hillier, of the RCA Manufacturing Company, on "Applications of the Electron Microscope." At this session presentation will be made of the Priestley Medal to Dr. Thomas Midgley, Jr., whose medal address is entitled "Demonstrations—A Historical Review." Dr. Karl August Folkers will receive the American Chemical Society Award of $1,000 in Pure Chemistry. He will make an address describing his work.

AT the annual meeting of the American Psychological Association, which is being held at Northwestern University on Wednesday, Thursday, Friday and Saturday of the present week, the address of the president, entitled "The Problem of General Quantitative Laws in Psychology," will be given by Dr. Herbert Woodrow, professor of psychology at the University of Illinois. In conjunction with the meeting of the association there are being held meetings of the American Association for Applied Psychology, with Dr. Edgar A. Doll, director of research at the Training School at Vineland, N. J., as president, who will give an address entitled "Scientific Freedom"; of the Society for the Psychological Study of Social Issues, with Dr. Floyd H. Allport, of Harvard University, as chairman, who will speak on "Methods in the Study of Collective Action Phenomena"; and of the Psychometric Society, of which Dr. Jack W. Dunlap, of the University of Rochester, is president, whose address is entitled "The Psychometric Society—Roots and Powers."

THE Baly Medal of the Royal College of Physicians, London, has been awarded to Dr. Edgar Allen, professor of anatomy and chairman of the department at Yale University, in recognition of his work on oestrogens. The Bisset-Hawkins Medal has been conferred on Sir Frederick Menzies for his work as chief medical officer of the London County Council.

THE honorary degree of doctor of science has been conferred by Tufts College on Dr. Charles H. Danforth, professor of anatomy at Stanford University. Dr. Danforth received the A.B. degree from Tufts College in 1908.

DR. SAMUEL M. FEINBERG, Chicago, has been elected an honorary member of the Argentine Society for the Study of Allergy.

DR. GERHARD DOMAGK, professor of morbid anatomy at Münster, who first introduced prontosil, has been made an honorary member of the Spanish Academy of Dermatology and Syphilology.

DR. WILLIAM HARVEY PERKINS, professor of preventive medicine in the School of Medicine of Tulane University, has been appointed dean of Jefferson Medical College, Philadelphia. He succeeds the late Dr. Henry K. Mohler.

DR. JESSE E. HOBSON, of the Westinghouse Electric and Manufacturing Company, has been made director of the department of electrical engineering of the Illinois Institute of Technology at Chicago. The institute was formed last year by the consolidation of the Armour Institute and the Lewis Institute.

ASSISTANT PROFESSOR M. E. ENSMINGER, of the Massachusetts State College, will become head of the department of animal husbandry of the State College of Washington at Pullman.

ANNA M. LUTE, seed analyst for the Colorado Agricultural Experiment Station, retired on September 1.

REAR ADMIRAL W. H. P. BLANDY, who has relieved Rear Admiral W. R. Furlong as chief of the Bureau of Ordnance of the Navy, has been named by the U. S. Navy Department as its representative on the Standards Council of the American Standards Association. Commander Alexander J. Couble, on duty in the Bureau of Ordnance, has relieved Commander F. T. Spellman, and has been named alternate for the chief of the Bureau of Ordnance on the Standards Council.

AT the recent annual meeting of the Woods Hole Oceanographic Institution, Dr. Vannevar Bush, president of the Carnegie Institution of Washington, was elected a trustee to serve until 1944.

DR. G. H. A. CLOWES, research director of the Eli Lilly and Company; Dr. S. C. Brooks, professor of zoology of the University of California at Berkeley, and Columbus Iselin, director of the Oceanographic Institution at Woods Hole, have been elected trustees of the Corporation of the Marine Biological Laboratory at Woods Hole. Dr. W. H. V. Osterhout was elected trustee emeritus.

CARL F. GRAHAM, head of the laboratory of the Procter and Gamble Manufacturing Company, Kansas City, has resigned to become head of the analytical section of the research department of the J. B. Ford Company, Wyandotte, Mich.

DR. H. CH. DYME, of the Kraft Cheese Company, has joined the staff of the Afral Corporation of New York City.

AT Columbia University A. Dejter Hinckley, assistant to the dean of the School of Engineering; Dr.

Charles O. Beckmann, assistant professor of chemistry; James L. Dohr, associate professor of accounting, and Dr. H. W. Farwell, professor of physics, have been appointed members of a committee to coordinate defense training in engineering, science and management.

DR. B. B. FREUD, chairman of the department of chemistry at the Illinois Institute of Technology, has been given a leave of absence for the coming academic year, to serve as colonel. He will be corps area liaison representative with the Sixth Regional Office of Civilian Defense.

SURGEON REAR-ADMIRAL G. GORDON-TAYLOR, vice-president of the Royal College of Surgeons, has been appointed a delegate of the college to attend the thirty-first annual Clinical Congress in Boston, as the guest of the American College of Surgeons.

DR. TRINO CASTRO, director of the Venezuelan Foundation to Combat Infantile Paralysis, arrived in New York on August 27 to attend the American Congress of Physical Therapy to be held in Washington. The foundation in Venezuela, which was recently established, is the first institution of the kind in South America.

DR. RALPH T. ST. JOHN-BROOKS, curator of the National Collection of Type Cultures at the Lister Institute, London, is spending a few months in studying the American Type Culture Collection at Georgetown University. He is investigating several taxonomic problems of joint interest to the two collections.

DR. MELVILLE J. HERSKOVITS sailed for Brazil on August 29, where he will continue his ethnological research during the coming year. The work has been made possible by a grant from the Rockefeller Foundation to Northwestern University. During his absence Dr. William R. Bascom will be acting chairman of the department of anthropology at Northwestern University. Herbert Passim has joined the staff as instructor.

Industrial Standardization reports that Senor Patricio Plante, director of Talleres Metalurgicos at Buenos Aires, vice-president of Iram, the national standardizing body of Argentina, has returned home following a month's stay in the United States. During his visit he conferred at length with the American Standards Association in order to bring about closer cooperation between the two organizations. This cooperation includes an arrangement by which the American Standards Association will circulate standards of the Argentinian body in draft form to secure criticism from interested American industries before their formal adoption. Iram, the largest and oldest standardizing body in Latin America, maintains for the use of Argentinian industries files of all the more important standards of the industrial countries of the world.

AN expedition to various parts of California to collect cryptogamic plants for the herbarium of Field Museum of Natural History recently left Chicago under the direction of Dr. Francis Drouet, curator of cryptogamic botany. Dr. Drouet was accompanied by Donald Richards, of the Hull Botanical Laboratory of the University of Chicago. Collecting will be continued until about the end of October. Several weeks will be spent in the northern mountainous counties, giving special attention to the algae and mosses of the region. A week will be devoted to collecting in the vicinity of San Francisco Bay to secure additional material of the numerous species of microscopic algae described from there in the past. The remainder of the time will be taken up with studies of the algal and moss flora of the San Joaquin and Imperial Valleys in the central and southern parts of the state.

IN the issue of SCIENCE of August 8, page 132, in the note giving an account of an expedition of the American Museum of Natural History, there is reference to a giant rodent which is incorrectly described. A correct account of the discovery of the remains of this rodent from the Oligocene is given in the article by Dr. George Gaylord Simpson, of the American Museum of Natural History, in the issue of SCIENCE for May 16.

NEEDS of the National Defense Program have caused the Civil Service Commission to announce an examination for junior meteorologist in positions paying $2,000 a year. There were not enough eligibles obtained as a result of the written test given under the junior professional assistant examination early this year. Accordingly, applications for a new examination will be accepted until June 30, 1942. The examination will be of the unassembled type—that is, no written test will be given. Applications will be rated as soon as possible after they are received at the commission's Washington office, and those rated eligible will have their names placed on the register set up as a result of the written examination given for the junior meteorologist option of the 1941 junior professional assistant examination. Further information can be obtained from the U. S. Civil Service Commission, Washington, D. C.

THE London *Times* states that German raiders recently set fire to the library of the Moscow Academy of Sciences. The fire was put out, however, before any of the 3,000,000 valuable books in the library were destroyed.

THE Industrial Research Institute, which is affiliated with the National Research Council, will meet in Detroit on September 26 and 27. The Hotel Statler has been designated as headquarters.

DISCUSSION

THE MAGNETIC CURRENT

NOT only electric currents but also magnetic currents flow through the universe.

I reached this conclusion by consecutive and persistent observation of single submicroscopic particles suspended in gases.[1] Using this method in my small condenser I can measure forces of an order of magnitude down to 10^{-10} dynes. Therefore my measurement of forces is more sensitive by the factor of 10^4 than any direct measurements of forces made so far. I was able to find new facts because methods of the highest possible sensitivity were used.

These observations can be summed up in two sentences:

(1) *Particles of matter, irradiated by a concentrated beam of light, move in a homogeneous electric as well as magnetic field in or against the lines of force.* (Electro-photophoresis, magneto-photophoresis). I have therefore concluded that these particles are charged under the impact of light. There exist not only electric but also magnetic charges.

(2) *Particles of the same kind and size move simultaneously toward and against the propagation of the light.* I called the movement away from the light lightpositive and that toward the light lightnegative longitudinal photophoresis.[2] I have therefore concluded that the light beam has potential differences along its propagation which cause the particles on which charges are induced to move in or against the direction of propagation. To the well-known oscillating fields in the beam of light have to be added these stationary electric and magnetic fields.

Before such fundamental conclusions can be drawn one must first see if there is no other explanation possible in accord with existing theories. Working for decades on the experiments and their interpretation I was forced to believe that only such an electromagnetic interpretation can be in accordance with all observable facts.

Heat or mechanical effects—so-called radiometer forces (Crookes)—can not account for these phenomena for the following reasons: There is a photophoretic force in liquids which is of the same order of magnitude as in gases, although no radiometer forces exist in liquids. Silver or copper particles in gases which are reflecting strongly exhibit a tremendous lightnegative movement, though they ought to be most heated on the side toward the light, and one would expect a movement away from the light. It seems impossible to explain the reversibility of the particles with corresponding reversals of the field. The energy of the fields alone is responsible for the orientation of the particles and is a quadratic function of the potentials. One therefore should not expect a change of direction in the motion of uncharged particles if the field is reversed. Were the movement due to heating effects, one could not explain why the particles move across and along the inner part of the beam instead of going entirely out of it. It would also seem strange that the movement of nickel particles under the influence of the geomagnetic field, as it was observed in my institute in Vienna (Austria), could be compensated by a superposed magnetic field of about 0.4 gauss. Furthermore, the movement of the particles always follows the lines of force, no matter from which direction the light may come. This would be impossible if the movement were due to heating effects. That some particles start to move suddenly from rest, that the photophoretic movement suddenly disappears and sometimes increases or decreases gradually, and many other observations can not be explained by mechanical or heat effects.

When I came to the conclusion that there are single magnetic poles (magnetic charges), it was therefore not necessary to ask if this agreed with existing theories, but rather whether there are any experimental facts that contradict it. It can be stated here that so far there are no experimental facts which contradict this conclusion of the existence of single magnetic poles. A study of the literature made with Leo Banet showed the following situation:

It has been the predominating opinion up to the present time that a real quantity of positive or negative electricity can be enclosed within an arbitrarily chosen geometric surface. But no matter how the surface is chosen it will always enclose the same amount of south and north magnetism. In other words, there are true quantities of electricity of either

[1] F. Ehrenhaft, *Annalen der Physik*, 56: 81, 1918; *Philos. Mag.*, 11: 141, 1931; *Annales de Physique*, (Paris) 13: 151, 1940; *Phys. Rev.*, 57: 562 and 659, 1940; *Jour. Franklin Inst.*, 230, 381, 1940; *Nature*, 147: 25, January 4, 1941; F. Ehrenhaft and L. Banet, *Nature*, 147: 297, March 8, 1941; F. Ehrenhaft, *Philosophy of Science*, 8, No. 3, 1941, "The Microcoulomb Experiment" (charges smaller than the electronic charge), see p. 36; F. Ehrenhaft and Leo Banet, *Philosophy of Science*, 8, No. 3, 1941. The older references about photophoresis are given in *Annales de Physique*, 13: 151, 1940.

[2] I have recently constructed the apparatus on which the above-mentioned phenomena can be seen at C. Zeiss Inc., New York. The latest descriptions of the apparatus and of the experiments are given in *Annales de Physique*, 13: 151, 1940.

sign, but no true magnetic ones. This statement has been made quite clearly by James Clerk Maxwell in his "Treatise on Electricity and Magnetism." Maxwell tried to prove that there was no such thing as true magnetism. May I remind you here that *in principio* it is impossible to prove from experiments that something is non-existent. Furthermore, the two experiments which Maxwell quotes are not conclusive. The first one states that a broken magnet gives two entire magnets with equal poles. If a non-magnetic piece of iron is broken, it can be observed that the fragments become magnetized in various ways on the broken ends. The effect is the same when a non-electrically charged glass or sulphur rod is broken, and shows at the ends various kinds of electric charges. This phenomenon is easily explained, since each breaking creates constriction. Each constriction, however, creates electricity and magnetism. The breaking experiment therefore, does not prove that true magnetism does not exist, as Maxwell stated.

The second experiment, which probably originated with the ancient Chinese and is quoted by P. Peregrinus (*anno* 1269), indicates that a magnet floating upon water directs itself but does not move. From this has been concluded that the amount of north and south magnetism is equal in each magnet. It is easy to perceive that the mobility of such a big floating magnet is much too small to show slight differences of charge. The particles on which my observations were made have a mobility a million times greater than that of the floating magnet of Peregrinus. Such particles irradiated with light move in a homogeneous magnetic field in the lines of force. Thus my sensitive experiment gives evidence of the existence of true magnetism. In other words, the Peregrini-Maxwell experiment turns out to be positive in my small condenser, when light is used.

My interpretation not only explains all observations in a rather simple manner, but also makes a number of new conclusions possible. One of these is that light magnetizes matter. Leo Banet and I succeeded in magnetizing small pieces of iron by means of irradiation with ultraviolet rays. Lilly Rona has expressed the idea that, concluding from these experiments, it should be possible to extract electricity from the beam of light originating from these stationary components. I believe that she is right, and that it could be done without the use of the photoelectric effect, that means without deteriorating and decomposing matter itself.

Under the influence of the light matter coagulates more readily because of the induced poles (charges). Sometimes the light separates amorphous and crystalline particles, and sometimes it makes crystals grow toward it (heliotropism of crystals).

Light causes irregularities in Brownian movement and therefore also in diffusion because of photophoresis.

Light causes ponderomotive forces to act upon matter apart from the effects of the light pressure. These ponderomotive forces are produced by the stationary components and induced charges. The latter have attracting or repelling effects.

I determined the magnitude of the charge of the magnetic ion and found it to be of the same order of magnitude as the electric one.

A new phenomenon which I called the trembling effect found a simple explanation, the frequent change of the magnetic charge occurring predominantly in weak magnetic fields in the beam of light.

Leo Banet has drawn important conclusions in regard to the effects on the sun and the earth that will be described in another paper.

Now I shall say a few words about the *magnetic current*. We have shown the existence of unipolar magnetic charges, which flow in a homogeneous magnetic field in or against the direction of the lines of force. This can be observed directly by means of a microscope. Therefore we have to deal with magnetic currents in a physical and technical sense. Around a magnetic current there exists an electric field. Furthermore a magnetic current produces heat in a medium conducting magnetism.

I have attempted to show that a beam of light causes or induces not only heat and electricity but magnetism at the same time.

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EFFECT OF THYMUS EXTRACT INJECTIONS ON RATS

FOLLOWING the report of Rowntree and coworkers[1] on the marked precocity of development and growth resulting from daily peritoneal injections of thymus extract to successive generations of rats, an attempt was made to repeat these findings. Correspondence with Drs. Rowntree and Hanson regarding the preparation of the extract greatly facilitated our work. No positive findings were obtained by us, even after carrying the rats to the F_4 generation. This was not reported at the time because we felt that perhaps the calves from which the thymus glands were obtained were not of the age specified.

With the publication of a modified method for the preparation of the extract by Steinberg,[2] the work was repeated, using this method of preparing the extract. This time we had a source of supply from which we could definitely obtain thymus glands from calves of the type stressed: local stock, milk-fed, two

[1] L. G. Rowntree, J. H. Clark and A. M. Hanson, *Am. Jour. Physiol.*, 109: 90, 1934.

[2] A. Steinberg, *Endocrinology*, 23: 581, 1938.

to six weeks old. As before, the rats were carried to the F_4 generation, with no positive findings resulting.

In both series of experiments, chemical findings for glutathione-like substances were always within the limits specified by the Philadelphia workers.

In connection with the above, it is well to note that negative findings in mice[3] and in rats[4] have been reported. Positive findings in rats have been reported from the Wistar Institute,[5] and positive findings regarding sexual maturity only in mice by Lafon.[6]

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A NUCLEUS-LIKE STRUCTURE IN A STAPHYLOCOCCUS

IN the course of studies on the variability of bacteria, we encountered a greenish-black staphylococcus which spontaneously dissociates into a yellow form.

The resting cell of this staphylococcus contains a single granule, spherical or slightly ellipsoidal in form and located near the center of the cell.

The growing cell contains either a single rod-like granule parallel to the long axis of the cell, or two granules spherical or ellipsoidal in shape and lying in the polar regions across the long axis of the cell. Instead of being rod-like, the granule may often be kidney-like.

These granules have the following properties: (1) They are pseudo-chromotropic with old solutions of methylene blue. (2) They are strongly acidic, staining deeply with methylene blue at pH 1.8–2.0. (3) They are not dissolved in 10 minutes by boiling water. (4) They are not dissolved by 0.02–0.5 per cent. sodium bicarbonate after a contact of over two hours. (5) They do not disappear when the cells are subjected to starvation for as long as 24 hours at 37° C. (6) They do not disappear upon frequent transferring. (7) They give a clear-cut Feulgen reaction under all the conditions listed above.

The constancy of these granules, their position, numbers and morphology in resting and growing cells, added to the properties enumerated above, speak strongly for their nuclear nature. Indeed they appear to fulfil all the requirements of nuclei.

The size of these granules, compared to that of the cell, is strikingly large, and yet we have been so far unsuccessful in our attempts at observation in the living cell, indicating that, in the living state, their refractive index is close to that of the cytoplasm.

We were unable to detect any type of reserve material in the cell of the staphylococcus.

The details and records of the present work will be published elsewhere.

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HOW MANY SPECIES OF PLANTS ARE THERE?

RECENTLY, during the course of investigations of general systematics of plants, it has been noted that current text-books of botany for university students contain discrepant and often contradictory statements of the number of existing species of Angiosperms. For example, according to a dozen books examined, the number of species of all Angiosperms varies from 133,000 to 175,000; of Dicotyledons 100,000 to 140,000; and of Monocotyledons 24,000 to 35,000. The number of Gymnosperms usually is said to be 500, and the total of all living species of plants is frequently estimated to be about 250,000. The methods used by the authors of these books in obtaining these figures is not revealed, but it is clear that the relatively simple expedient of consulting reasonably accurate recent sources of taxonomic data was not employed.

It occurred to me, therefore, that, in view of the fact that these estimates appear to have been based upon antiquated data, it may be worthwhile to present a more accurate summary. According to a compilation made partly from the eleventh edition (1936) of "Die Syllabus der Pflanzenfamilien" (Engler and Diels), and partly from recent monographs and other sources, the Angiosperms contain a total of 195,000 known species; of these, 155,000 are Dicotyledons, and 40,000 are Monocotyledons. There are approximately 640 species of Gymnosperms. On the basis of figures supplied by G. M. Smith,[1] there are (with the addition of Bacteria) 107,570 species of Thallophyta and 23,000 species of Bryophyta. The Pteridophyta contain about 10,000 species, of which 9,000 belong to the Filicales.[2]

Thus, the conclusion may be drawn, that on a conservative basis, the approximate total number of different species of known living plants is slightly in excess of 335,000. The rate of discovery and description of new species of flowering plants during the twenty-five year period from 1910 to 1935 has been reported by E. D. Merrill as averaging at least 4,800 per year.[3]

G. NEVILLE JONES

UNIVERSITY OF ILLINOIS

[3] G. van S. Smith and E. E. Jones, *Proc. Soc. Exp. Biol. and Med.*, 43: 157, 1940.

[4] H. B. Vickery, Carnegie Inst. Wash. Year Book No. 37, 335, 1937–8; H. Chiodi, *Rev. de la Soc. Argent. de Biol.*, 14: 326, 1938; W. O. Nelson and D. A. McGinty, quoted by Nelson in "Sex and Internal Secretions," 2nd Edition, 1939, Chapter XXI.

[5] *Wistar Institute News Letter*, April 15, 1936.

[6] M. Lafon, *Jour. Exp. Biol.*, 13: 140, 1936.

[1] "Cryptogamic Botany," Vol. 1, 1938, McGraw-Hill Book Co.

[2] C. Christensen in Verdoorn's "Manual of Pteridology," The Hague, 1938.

[3] *Memoirs Brooklyn Botanic Garden*, 4: 57–70, 1936.

QUOTATIONS

THE GIANT CYCLOTRON[1]

WITH so much creative human talent employed in devising increasingly powerful engines of destruction it is at least some comfort to know that to-day in the United States work is proceeding on two of the mightiest instruments the world has seen for the peaceful exploration of the universe. One is the 200-inch telescope nearing completion on Mount Palomar, California; the other is the giant cyclotron under construction at Berkeley, California. The new telescope will explore the outer reaches of the universe, the realm of the infinite; the new cyclotron will probe the inner reaches of the universe, the realm of the infinitesimal. The telescope was made possible by an appropriation in 1928 of $6,000,000 by the International Education Board, established by Mr. John D. Rockefeller, Jr. This last year the Foundation appropriated $1,150,000 to the University of California for the construction and housing of the cyclotron.

From the time of Democritus, the natural philosopher has tried to probe inside the matter of which our physical universe is built in order to discover the nature of its smallest parts and the laws which govern them. For centuries there could be nothing but vague speculation, for suitable experimental procedures were not available. But brilliant advances have been made since the turn of the present century, and in forty years of research a flood of light has been thrown on the nature of atomic structure. Two decades ago this inner citadel of the universe was successfully attacked by shooting into the atom small projectiles of such high speed that they disrupt the internal pattern. Then from a study of the erupted fragments, of the mutilated remainder, and of the battered projectile, new knowledge was obtained of the atom's structure.

The most successful device for this purpose has been the cyclotron, invented by Professor Ernest O. Lawrence, of the University of California. In essence the cyclotron is a machine for imparting extremely high velocities to atomic particles by means of electrical impulses. The particles, which are the bullets of the gun, are charged atoms. Whirling in ever-widening circles in a chamber mounted between the poles of an immense magnet, these particles are sped faster and faster by alternate changes of an electrical field from negative to positive and vice versa until they are finally shot out through an opening to smash against a target whose atoms are to be cracked by their impact. It is as if a stone were whirled on the end of an elastic cord in a constantly enlarging orbit until at last it flies off at a tangent with tremendous force. When these bullets emerge from the cyclotron they are in the form of a steady beam, moving at velocities which may exceed 100,000 miles a second. At such high speeds they constitute the most powerful concentrations of energy ever controlled by man.

There are now in operation throughout the world some thirty-five cyclotrons of varying sizes. Of these, twenty-four were either built by, or are now being operated by, men who were trained in Lawrence's laboratory. Lawrence himself has built a sequence of cyclotrons of increasing size, varying in weight from 500 pounds to some 220 tons, and producing a beam ranging from 80,000 volts in his smallest cyclotron to 16,000,000 volts in his largest. The new giant cyclotron will contain over 4,000 tons of steel and copper in its magnet alone and will produce a beam whose voltage will range from 100,000,000 to perhaps 300,000,000. The beam of the largest cyclotron now operating penetrates, in air, about five feet; the beam of this giant instrument will penetrate 140 feet.

But of what use is this machine and what can it do for man? The chief practical application to date has been in the use of the beam to produce radioactive matter. The new array of radioactive substances which has resulted will almost surely have an important relationship to current scientific problems; but one broad field of application has already been clearly demonstrated: these artificially radioactive atoms are the familiar "tagged atoms" which are now being used in chemical, biochemical, physiological and other laboratories all over the world in a wide range of basic research which would be quite impossible were it not for this unique new material.

Furthermore, the beam of exceedingly high-speed particles can be applied, like x-rays, gamma rays, and other types of radiation, directly to living organisms, and the effects can be analyzed and ultimately utilized. It will require years to investigate the efficacy of beams of different composition and intensities on various vital processes; but experiments have already shown, for example, that beams of neutrons can penetrate deeply into living tissue and can there release local radiations which can be, but need not be, intense enough to kill cells. These further applications are now in their first tentative stages. It is as difficult to predict the exact nature of their use as it would have been in the case of x-rays at a similar point in their development.

But if these results are being obtained by cyclotrons now in existence, why build this new giant machine? The answer takes us into the field of ex-

[1] From the President's Review of the work of the Rockefeller Foundation for 1940. Raymond B. Fosdick.

ploration and the insatiable intellectual curiosity which is the mark of civilized man. The most powerful cyclotrons now in existence produce particles whose speeds, when fired at atoms, enable them to knock off only the external and more loosely bound features of the atoms under attack. It is at this point that the new giant cyclotron, now under construction, is of critical importance, for it is designed to produce projectiles so powerful that they can penetrate and explore the nucleus itself.

It is essential to realize the significance of this point. During the last forty years, science has learned much about atomic structure. One outstanding mystery, however, remains, and in many senses it is the major mystery. Relatively little is known about the nucleus, the central core of the atom. There is evidence that this nucleus possesses a discoverable structure, that it is formed of certain elementary units in accordance with laws with which we are not familiar; and physicists to-day consider its investigation the most important present problem in physical science. Here in the interior of the nucleus is the one essentially unexplored part of our universe. It is a world into which we have hitherto been powerless to enter; and the urge to penetrate, to explore and to analyze is irresistible.

This urge, moreover, is heightened and justified by the conviction that this virgin territory will prove to be rich. Practically all the energy of the atom, for instance, is stored within the nucleus; and it is the nucleus which really determines the character of an atom and is hence ultimately responsible for all the properties of matter. Furthermore, there is evidence that the essential forces which bind the nucleus together are due to an elementary particle called a "mesotron." These same mesotrons play an important rôle in cosmic rays; and if more could be learned about mesotrons it would immediately throw light not only on this other perplexing problem, but on still further riddles with which science is now grappling on the frontiers of knowledge.

The real case for building a great cyclotron rests upon its ability to make accessible a new infinitesimal world—the interior of atomic nuclei, with all the possibilities of fresh knowledge that may there reside. It is an adventure in pure discovery, motivated by the unconquerable exploring urge within the mind of man.

In this sense, therefore, the new cyclotron is more than an instrument of research. Like the 200-inch telescope it is a mighty symbol, a token of man's hunger for knowledge, an emblem of the undiscourageable search for truth which is the noblest expression of the human spirit.

SCIENTIFIC BOOKS

HUMAN NATURE

Human Nature and the Social Order. By E. L. THORNDIKE. xx + 1019. Macmillan. 1940.

THIS book is of monumental proportions with its half million words and weight of nearly 3½ pounds. Because of its forbidding size it lay on my desk for weeks before I could muster courage to tackle it. Once started, however, I read the book from cover to cover with unflagging interest in the contents and with many chuckles over the author's way of putting things. My chief complaint is that it was not published as two volumes instead of one, so that it could be read by the nearsighted with less fatigue of the arms and shoulders.

The material is divided into 38 chapters and 6 appendices. Part I (400 pages) deals with such topics as the ABC of behavior, human abilities, wants and their measurement, mental dynamics, individual differences, the roles of nature and nurture, conflicts of wants and the evaluation of satisfactions. Among the leading problems treated in Part II are the science of philanthrophy, the welfare of future men (eugenics), the welfare of the present, utility and disutility, natural resources and capital, labor and management, buying and selling, payment for human factors, money and credit, ownership, the psychology of capitalism, political science, human relations, criteria of a good government, rulers and methods of ruling, the aims of government, human nature and the law, the improvement of law, human nature and reform.

A statement in the preface says that the book is intended not only for college students of the social sciences but also for thinking men and women generally. In my judgment it will be useful and stimulating to both groups despite the fact that it is neither a systematic treatise on social psychology nor an all-round introduction to the social sciences. Part I is an exposition of the facts and principles of psychology which the author considers most important for the social science student. Here 75 pages are devoted to abilities, 55 to individual differences, 125 to wants and mental dynamics, 57 to heredity and environment and 50 to evaluation of satisfactions. In these sections the author draws extensively upon his earlier books, but there is much new material and the old is effectively reorganized and freshly stated. Part I presents a large amount of psychological information of the kind social scientists most need but get little of from the average text-book in social psychology. The

emphasis upon abilities, wants, individual differences and genetic factors sets the tone for the entire volume. The treatment is factual and realistic with a profusion of concrete illustrations expressed in striking (sometimes bizarre) word pictures. In places, however, it is not easy reading. Many of the concepts and distinctions that probably seem to the author quite elementary will present difficulties even for the superior student who has not had considerable course work in psychology and statistical methods. There are occasional passages that would have benefited from greater attention to clarity of statement. Outstanding qualities of the author's style are vigor, originality and pungency.

Part I and Part II are essentially quite different. Part I is psychological throughout and is concerned almost exclusively with fields in which the author himself has made research contributions of high merit. Part II (600 pages) is not to any great degree psychological but gives the author's personal reactions on a vast miscellanea of problems in economics, political science and social welfare. The discussion of these problems, which lie so largely outside the realm of present-day psychological science, is rightly intended to emphasize the extent to which their solutions must take account of psychological phenomena. On a good many of the issues discussed in Part II the psychologist, as psychologist, can at present make little or no contribution. Some of the discussions could as well have been written by a mathematician, chemist, biologist or lawyer. What Thorndike has to say is nearly always thought-provoking, whether he speaks primarily as psychologist or not, but it is probably these excursions into alien territory that will draw the most criticism.

I estimate that nearly 20 per cent. of Part II is taken up by quotations, often long ones, from many authors. The quotations are apropos and usually interesting but distract somewhat from the unity of treatment. Part II in general is likely to impress the reader as having less organization than would have been desirable.

I have stated above that this book "is neither a systematic treatise on social psychology nor an all-round introduction to the social sciences." Numerous topics which bulk large in the average text in social psychology are omitted or only casually mentioned. For information on relative emphasis it is instructive, even if sometimes perhaps misleading, to compare the index of a book with that of another in the same general field. I have made some comparisons of this kind between Thorndike's book and Kimball Young's "Social Psychology."[1] The figures that follow show for selected topics the number of references to each in the subject indexes. The first figure in each pair is for Thorndike, the second for Young.

More frequent mention by Thorndike:	
Abilities (or intelligence)	14–4
Capital (or capitalism)	10–1
Genes (or heredity)	25–3
Individual differences	21–10
Mastery	11–0
Measurement	12–0
Needs (or wants)	17–0
Prediction	7–0
Rewards	11–0
Rulers (or ruled)	4–0
Russia (or Soviet)	14–0
Satisfactions	12–0
Tests	8–0
Wealth	6–0
More frequent mention by Young:	
Attitudes	6–24
Censorship	1–37
Conditioning	2–9
Crowd	0–31
Cultures	0–30
Emotions	0–25
Fads (or fashions)	1–37
Gangs	0–4
Interaction	0–7
Language	0–30
Laughter	0–8
Leadership	0–37
Legends (or myths)	0–18
Newspapers	0–29
Personality	2–30
Play	1–13
Prejudice	0–35
Stereotypes	0–21
Propaganda	3–40
Public opinion	0–32

Examination of the name indexes discloses similarly striking contrasts even when the comparison is limited to names of writers who have dealt with social issues. The following figures (again in the T-Y order) are more or less typical:

F. Allport	2–15
Bentham	7–0
Burgess	0–7
Cooley	0–7
Dewey	1–11
Freud	3–11
Holmes (Justice)	7–0
McDougall	1–14
W. I. Thomas	2–16
E. A. Ross	0–9
Sumner	0–7
Veblen	14–9
G. Wallis	7–2
Webb (B. or S.)	12–0

The figures just given make it clear that this book

[1] Knopf, 1930, pp. 38 + 674.

is not just another text in social psychology. For the most part it leaves the concepts and problems of sociology to the sociologists, especially the problems of acculturation and human interaction. Its most distinctive contribution is in the emphasis placed upon the social significance of individual differences in abilities, character, wants and satisfactions, and upon the genetic causes of such differences. Thorndike does not deny the importance of good environment, but he never forgets that genes set the limits to its effects. With sly humor he notes that "the perfectibility of human nature is wisely put by religions in a heaven with not only optimal environment but also infinite time." Numerous passages could be cited in which he pays his respects to the biological ignorance that underlies egalitarian social philosophies. Certainly very few writers have so boldly expressed the implications (as he sees them) of the doctrine of individual differences for economic and political theory.

Not every one will agree with Thorndike on what the true implications are. Some who agree with him completely about the potency of genes will be unable to accept all the conclusions he deduces from that premise. For Thorndike the fact that the ability of the gifted far transcends that of the masses, together with the fact that there is a positive correlation between ability and character, calls for a political system in which power would be largely concentrated in the hands of a benevolent aristocracy composed of the able and the good and in which equal suffrage would be replaced by some scheme of weighted ballots. The author believes that our present "aversion to government by experts is on a level with aversion to medical treatment or sanitation by experts." One may question whether he has given due consideration to the dangers inherent in even the best aristocracies and whether he is not banking too heavily on the practical consequences of a slight positive correlation between intelligence and character. It may well be, however, that a vigorous presentation of this point of view will serve as a useful antidote to the sentimental political and social philosophies that ignore or deny heredity differences and attribute magic influences to factors of environment.

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SPECIAL ARTICLES

FAILURE OF BARLEY TO FIX MOLECULAR N^{15}

THE testimony of centuries of experience in practical agriculture has established the respective nitrogen depleting and nitrogen replenishing natures of non-leguminous and leguminous crops. Despite the weight of practical and experimental evidence against the conclusion, periodic reports reassert that non-leguminous plants can fix atmospheric nitrogen.

Results were presented in this journal by Ruben, Hassid and Kamen[1] indicating the fixation of radioactive N^{13} gas by the fresh tops of barley plants and the lack of fixation by tops boiled in water before exposure to N^{13}. As N^{13} has a half life of but 10.5 minutes, these experiments were necessarily of very short duration, the barley tops having been exposed to N^{13} for only 20 minutes.

The stable nitrogen isotope, N^{15}, offered us a means of tracing nitrogen fixation without the time limitation imposed by the radioactive isotope. Barley seeds were dehulled and then rendered bacteria-free by treatment with 70 per cent. ethyl alcohol followed by calcium hypochlorite solution carrying 3 per cent. available chlorine. The seeds were germinated aseptically and transferred to culture tubes containing thoroughly washed quartz sand to which a nitrogen-free nutrient salts solution had been added prior to sterilization. Tubes containing bacteria-free red clover plants and red clover plants with added root nodule bacteria (*Rhizobium trifolii*) were prepared in the same manner. Cresol red[2] in side bulbs on the tubes indicated when CO_2 was needed, and this gas was added to the atmosphere as required during the experiment. The plant culture tubes were sealed to a common manifold, evacuated and supplied with a gas mixture of 20 per cent. oxygen and 80 per cent. nitrogen. The nitrogen gas had 13.5 atom per cent. N^{15} excess (*i.e.*, 13.87 per cent. N^{15}, the normal abundance of N^{15} being 0.37 per cent.) and was freed of combined nitrogen compounds by passage through alkaline $KMnO_4$ and H_2SO_4.

Each group of plants, bacteria-free barley, bacteria-free clover and inoculated clover, received the same gas mixture, and the gas during the entire experiment was free to diffuse among the tubes through their cotton plugs. Air controls were grown in the same manner. The plants of experiment 1 were harvested after 42 days, subjected to Kjeldahl digestion, the NH_3 distilled and then converted to N_2 with alkaline hypobromite.[3] The N_2 was analyzed for the N^{15} isotope with a mass spectrometer.

In a second experiment, which did not include the bacteria-free clover culture, 8.1 atom per cent. excess

[1] S. Ruben, W. Z. Hassid and M. D. Kamen, SCIENCE, 91: 578, 1940.

[2] Elizabeth M. Smyth, SCIENCE, 80: 294, 1934.

[3] D. Rittenberg, A. S. Keston, F. Rosebury and R. Schoenheimer, *Jour. Biol. Chem.*, 127: 291, 1939.

N^{15} nitrogen gas was used. The plants were harvested after 56 days and analyzed. The experimental results are given in Table 1 as atom per cent. N^{15} excess of plants over the average values of air control plants.

TABLE 1

	Atom per cent. N^{15} excess of plants over average of air controls	
	Exp. 1	Exp. 2
Bacteria-free barley	-0.010 ± 0.005*	-0.006 ± 0.005
Bacteria-free clover	-0.004 ± 0.005	.....
Inoculated clover	2.469 ± 0.061	0.689 ± 0.052

* 0.005 per cent. represents the standard deviation of spectrometer readings for all determinations on the bacteria-free plants; the standard deviations of readings for the inoculated clover (calculated for individual samples) are higher, since the error of measurement is greater at higher N^{15} concentrations. The regular occurrence of negative values for bacteria-free plants is merely fortuitous.

These data show that if either barley or bacteria-free clover fixed any nitrogen, the amount fixed was within experimental error, whereas fixation by inoculated clover resulted in the accumulation of large quantities of N^{15}.

By calculation from the data of Ruben *et al.*,[1] we can find if their success and our failure to observe fixation arises from a difference in the sensitivity of the stable and radioactive tracer methods. These investigators used 30 grams wet weight of barley tops which, assuming 75 per cent. moisture and 3 per cent. nitrogen on a dry weight basis, would contain about 225 mg of nitrogen. The authors stated that during the experiment the plants assimilated an amount of N_2 which "corresponds roughly to 0.01 cc of N_2"; 0.01 cc of N_2 (0.0125 mg N_2) constitutes 0.00556 per cent. of the total nitrogen of the plants. We can calculate what the final N^{15} content of our barley plants should be if we assume that the rate of fixation reported by Ruben *et al.*[1] occurred uniformly during the period of our experiment 1. Since 42 days' exposure is 3,024 times the 20-minute treatment of Ruben *et al.*,[1] 16.8 per cent. (*i.e.*, 0.00556 per cent. $\times$ 3,024) of the total nitrogen of the plants would be fixed during the experimental period. But as 13.5 atom per cent. excess N^{15} was used, the observed N^{15} value would be 2.27 atom per cent. N^{15} excess (*i.e.*, 16.8 per cent. $\times$ 0.135).

The value 2.27 atom per cent. N^{15} excess, which we would have found had our barley plants fixed nitrogen at the same rate as Ruben *et al.*[1] report for N^{13} fixation, is 454 times the standard deviation of our measurements with the mass spectrometer. It is about the same value as we actually observed with inoculated clover plants.

Since the fixation experiments with barley were completely negative, one can but speculate as to the reason that the twenty-minute exposure of excised barley tops in the experiments of Ruben *et al.*[1] resulted in an uptake of N^{13}. These workers extracted the barley plants with boiling 80 per cent. ethyl alcohol, boiled the extract in a stream of air in an effort to drive off N_2, and then detected radioactivity in the boiled extract. It hardly seems likely that the observed N^{13} uptake can be attributed to fixation by the small number of bacteria carried by the plant tops or, in view of our results, to a true nitrogen fixation by the plant tops themselves. Ruben *et al.*[1] state, "These experiments with N^{13} do not necessarily prove that a net uptake of N_2 has occurred, since the existence of reversible (interchange) reactions involving N_2 is possible." However, Burris and Miller[4] demonstrated the absence of any interchange reaction in *Azotobacter vinelandii*, which was vigorously fixing N_2 in a non-equilibrium N^{15}-excess atmosphere. The possibility remains that a non-specific surface adsorption of N_2 by fresh barley tops and a failure to completely remove this N_2 containing N^{13} accounts for the radioactivity detected by Ruben *et al.*[1] In our experiments it is obvious that the Kjeldahl treatment would eliminate all adsorbed N_2.

The complete lack of fixation of the stable N^{15} isotope by bacteria-free barley and bacteria-free red clover plants under conditions identical with those supporting active fixation of N^{15} by red clover inoculated with *R. trifolii* supports the generally accepted conclusion that non-leguminous plants and leguminous plants in the absence of the root-nodule bacteria are unable to fix molecular nitrogen.

In addition to the question of nitrogen fixation by non-leguminous plants, positive and negative reports in the literature present controversies concerning the nitrogen fixing ability of germinating pea seeds, excised root nodules with added oxalacetic acid, and root nodule bacteria in the absence of the host plant. Thus far we have been unable to demonstrate fixation of N^{15} by any of these biological agents, whereas azotobacter and leguminous plants with root nodule bacteria fix N^{15} readily.

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CROWN GALL PRODUCTION BY BACTERIA-FREE TUMOR TISSUES

CROWN gall has in the past been produced only by inoculation of a host plant with *Phytomonas tumefaciens* (Smith and Town.) Bergey *et al.* either as a pure culture or in the form of a preparation of tissues infected therewith. Although crown-gall tissues have not always yielded cultures of the organism, it has been presumed that the bacteria were present or at least had been present at some stage in the development of the tumor. The production of tumors with-

[4] R. H. Burris and C. E. Miller, SCIENCE, 93: 114, 1941.
[5] National Research Council fellow.

out direct stimulation from the bacteria, although envisioned as a possibility by certain workers, has not previously been demonstrated, nor has that possibility been given serious credence by other investigators.

One of us has recently confirmed the work of Smith *et al.*,[1] showing that true secondary tumors developed in sunflower plants at a distance of several internodes from the site of the primary tumor, even when inoculations were made into fully elongated internodes at a distance from the apical bud.[2] Many of the secondary tumors were found to be sterile by the usual bacteriological criteria. The bacteria-free secondary tumors appeared, therefore, to be admirably suited for an experimental study of the question as to whether host cells under the influence of the bacteria acquire the capacity for autonomous growth.

Recently developed techniques for the *in vitro* cultivation of excised plant tissues[3] were applied to the study of secondary tumors. Tissue fragments from the interior of a series of such tumors were removed aseptically and placed in 125 ml Erlenmeyer flasks, each containing 50 ml of White's standard glycine-thiamin nutrient[4] stiffened with 0.6 per cent. of thoroughly leached agar. Out of 107 original isolations from tumors, 2 were contaminated with bacteria and 4 with molds. Out of 50 control cultures taken from healthy plants, 4 were contaminated with bacteria and 3 with molds. The larger tissue masses available in the tumors and the consequent greater ease of manipulation were doubtless responsible for the lower incidence of contaminations in tumor cultures.

Cultures capable of continued rapid growth were not established from any of the small petiolar tumors nor from the petioles of healthy plants. On the other hand, out of 37 isolations from large secondary tumors from the stems at nodes, 19 grew successfully. Six isolations were carried through 3 or more passages, being divided at each passage. Two strains, one isolated on February 10, 1941, the other on March 25, 1941, were retained for detailed study. The first of these isolations has, at the time of writing (August, 1941), been maintained through 13 successive passages, has been divided into 482 pieces, each several times as large as the original, and has undergone a theoretical increase[5, 3] in volume of approximately 450,000 times. Throughout this manipulation, it has been constantly in contact, both at intact and at freshly cut surfaces, with a nutrient shown by ourselves and by others to be capable of supporting a profuse growth of *Phytomonas tumefaciens;* yet, out of the 482 cultures not a single one has developed any bacterial growth. Attempts to isolate bacteria from these cultures by grinding and plating on nutrient agar or broth have consistently failed. When cultures were ground and the paste injected into sunflower or tomato plants, no galls were produced such as regularly appeared when a paste prepared in a similar manner from young primary tumors was injected. The results seem to furnish almost unquestionable evidence that these tissues, which multiply rapidly, nevertheless do so without continued stimulation from crown-gall bacteria. Their capacity for autonomous growth appears established.

Tumor tissues grown *in vitro* are colorless or, especially just after being divided, slightly tinged with brown from oxidative products, scattered remnants of dead cells, etc. The surfaces are rough, covered with irregular unorganized protuberances, and may put forth unorganized outgrowths either along the agar or up into the air. They are firm but easily cut and of uniform texture. Histologically they are mostly parenchymatous with scattered scalariform elements. These elements form a structure closely resembling that of crown-gall tissue stimulated by *Phytomonas tumefaciens* when inoculated into parenchymatous tissues of the host.

Tissues from cambial and procambial regions of healthy sunflowers have likewise been isolated in culture but present a very different picture. In the weeks that they have been maintained, they have been carried through 5 passages, but their growth rate has been so slow that the volume increase during this period has been of the order of 30 times as compared to about 400 times for the gall tissues over a corresponding period. Cultures of normal tissue maintain their outlines, whereas gall cultures grow as irregular or subglobular masses. Normal tissue cultures regularly contain chlorophyll, are woody in texture and frequently produce roots, a phenomenon not observed to date in cultures of gall tissues.

At the end of 5 successive passages *in vitro*, tumor cultures were grafted back into young healthy sunflower plants. Of these, 5 implants had, at the end of 7 weeks, grown into typical crown-gall tumors having diameters up to 1 cm, one plant was accidentally broken, and 4 implants failed to grow. Similar results have been obtained with a second series of grafts using cultures from the 6th passage and a third series using cultures from the 10th passage. Attempts to isolate bacteria from one of the tumors by grinding and plating in nutrient dextrose agar failed. The results seem to indicate that the tumor-inducing capacity has been retained by these bacteria-free tissues through at least 10 successive passages.

[1] E. F. Smith, N. A. Brown and L. McCulloch, *U. S. Dept. Agr., Bur. Pl. Ind., Bull.* 255, 1912.
[2] A. C. Broun, *Phytopath.*, 31: 135–149, 1941.
[3] P. R. White, *Am. Jour. Bot.*, 26: 59–64, 1939.
[4] P. R. White, *Plant Physiol.*, 14: 527–538, 1939.
[5] P. R. White, *Plant Physiol.*, 9: 585–600, 1934.

o. Preliminary examination has shown the induced ors to have a histological structure considerably re uniform than that of most crown galls, with nsive hyperplasia but relatively little disorganiza-. This last feature is quite marked and may pos-y be due to the uniform distribution of the mecha-n of hyperplasia in contrast to the scattered and lized centers of stimulus characteristic of bacterial s. Fusion with the host tissue was excellent, al-gh growth was mostly if not entirely a function the transplant, as is the case with transplanted nal neoplasms. It is clear from these results that affected tissues have undergone a drastic change ch is indicated, first, by their capacity to produce galls, a quality not found in normal tissue, and, second, by their behavior *in vitro,* where their growth habits differ markedly from those of normal tissues under identical conditions. That this change was originally brought about by some stimulus from the crown gall organism seems clear. That its maintenance is not dependent on the continued presence of the bacteria is equally clear. Further details will be published elsewhere.

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SCIENTIFIC APPARATUS AND LABORATORY METHODS

LLODION FIXATION: A NEW IMMUNOLOGICAL REACTION

THE study of filterable viruses and of diseases ed by them is handicapped by the relative lack *in vitro* reactions which can detect very small unts of virus substance. The present dependence pathological processes for the identification of ses involves a considerable time factor. As an proach to the solution of these difficulties experi-ts were undertaken with a well-known immuno-al system in an effort to increase sensitivity, e this would appear to be the first requirement ny new method. The system employed was the tion between antipneumococcus serum and the ific capsular polysaccharide of the pneumococcus. er optimum conditions, specific precipitin reac-s can be obtained with polysaccharide dilutions as as 1–5,000,000; with complement fixation to 0,000,000.

he first series of experiments involved the adsorp-of *antibody* on the surface of collodion particles, eby artificially increasing the size of the antibody. y workers have adsorbed *antigen* on collodion or r particles (*cf.* review by Cannon and Marshall[1]) have demonstrated increased sensitivity as regards tion of antibody. Cannon and Marshall[1] sensi-d collodion pellets with egg albumin; Weir[2] used ereulin sensitized pellets for the study of antibody mation in animals. Our experiments in the adsorp-of antibody were successful under very limited litions; the most fortunate results were obtained the use of purified horse and rabbit antipneumo-us sera. Particles so sensitized were agglutinated he presence of the specific capsular polysaccharide ilutions of approximately 10^{-10}. The details of these experiments will be published elsewhere. It may be said, however, that these systems are very sensitive to non-specific factors, such as broth, proteins, changes in electrolyte concentration, etc., and hence are not suitable for the general purposes of the method most desired.

In an approach to a more satisfactory method it was recalled that although both antigens and antibodies are not remarkable for adsorptive phenomena, the antigen-antibody complex is extraordinary in this respect: the complement fixation reaction is an example of this property.[3] Experiments were therefore undertaken to learn whether the antigen-antibody complex would adsorb collodion particles, thus, as it were, magnifying immunological reactions.

Collodion particles were prepared after the method of Cannon and Marshall,[1] the stock suspension being adjusted to a density such that a 1–10 dilution would match number 3 on the McFarland scale.[4] Suitable and constant quantities of collodion suspension are added to varying amounts of antigen in agglutination tubes. To these mixtures are then added appropriate amounts of immune sera; the total volume is then brought to 1.0 cc by the addition of physiological saline. With systems of some refinement, such as that with antipneumococcus serum, the tubes remain at room temperature for one hour and are then centrifuged for 5 minutes at 500 r.p.m. Each tube is "flipped" and the amount of particulate agglutination estimated. Control tubes, not containing antigen, give free and smooth resuspension. With less refined systems, such as the viruses, the tubes are placed in the icebox overnight, then centrifuged and read. An example of results obtained with the antipneumococcus system is given in Table I.

These results present two important points: (a) The

P. R. Cannon and C. E. Marshall, *Jour. Immunol.*, 38: 1940.
J. M. Weir, *Proc. Soc. Exper. Biol. and Med.*, 46: 47,

[3] K. Goodner and F. L. Horsfall, Jr., *Jour. Exper. Med.*, 64: 201, 1936.
[4] J. McFarland, *Jour. Am. Med. Assn.*, 49: 1176, 1907.

TABLE I

COLLODION FIXATION IN ANTIPNEUMOCOCCUS SYSTEM

0.1 cc antiserum 0.3 cc saline 0.1 cc collodion suspension 0.5 cc capsular polysaccharide dilution	One hour at room temperature Centrifuged "Flipped" and read in terms of agglutinated particles

Antisera:	Horse antipneumococcus Type I		Rabbit antipneumococcus Type I
Pneumococcus capsular polysaccharide:	Type I	Type III	Type I
Antigen dilution			
10^{-5}	++++	–	+++
10^{-6}	+++	–	++
10^{-7}	+++		–
10^{-8}	++		–
10^{-9}	+		–
10^{-10}	+		–
Saline control	–		–

TABLE II

COLLODION FIXATION IN VIRUS-ANTIVIRUS SYSTEMS

0.1 cc antiserum 0.3 cc saline 0.1 cc collodion suspension 0.5 cc virus solution (1–100 dilution of original material)	Overnight in ice box Centrifuged "Flipped" and read in terms of agglutinated particles

Antiserum	Virus	Re
Normal goat serum	Fluid from chick embryos infected with "Influenza A" virus	
Serum of goat immunized with "Influenza A" mouse lung preparation	" " " "	+
" " " "	As above but infected with "Influenza B"	
Normal human serum	Fluid from chick embryo infected with yellow fever virus	
Human serum from convalescent yellow fever	" " " "	+

great delicacy of the reaction with antipneumococcus horse serum—in other experiments the limiting dilution of capsular polysaccharide was determined to be greater than 10^{-10}. (b) Antipneumococcus rabbit serum does not give this effect. In polysaccharide concentrations which produce a visible precipitate the visibility of the reaction is sharpened by the enmeshing of collodion particles, but there is no enhancement of limiting dilution. This result is precisely opposite that obtained with complement fixation, for with this reaction antipneumococcus rabbit serum gives positive results whereas horse serum fails. In so far as can now be determined the paradoxical results follow precisely a classification of species reported earlier.[5]

Although paradoxical in a species sense this reaction of collodion fixation bears many analogies to complement fixation. Thus, if the collodion particles are present at the time of antigen-antibody interaction an excellent result is obtained, whereas if they are added one hour after admixture of antigen and antibody the result is usually entirely negative.

That this method is applicable to work with filterable viruses is demonstrated by the results shown in Table II.

There is evidence to indicate that in virus systems the species derivation of the immune serum may be very important. Thus, in various experiments, human and goat immune sera have given positive results, whereas experiences with monkey and rabbit sera have thus far proven negative. It is probable that much will have to be learned of variables such as this before any general application to virus work can be carried out. Work already completed shows that the method can be applied successfully to the identification and typing of influenza virus in throat washings, to the identification of yellow fever virus, to the determination of the presence of antiviral antibodies in the sera of persons recovered from yellow fever, to the study of antibodies reactive with malarial parasites in both human and animal sera, to the reaction between poliomyelitis virus and specific antisera. The possibilities of application appear to be extraordinary in scope. This subject will be discussed at length in another place.

[5] F. L. Horsfall, Jr. and K. Goodner, *Jour. Immunol.*, 31: 135, 1936.

SUMMARY

Collodion fixation by immunological complexes presents a method of great delicacy—about 1,000 times that of any heretofore described reaction. The delicacy is of an order which may permit the *in vivo* identification of filterable viruses.

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